PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) METHOD OF PHOTOGRAPHIC TRANSFER

(71) We, LICENTIA PATENT-VERWALTUNGS-G.M.B.H., of 1 Theodor-Stern-Kai, 6 Frankfurt 70, Federal Republic of Germany, a German Body Corporate, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method for photographic transfer of an original pattern to a substrate coated with a photo-sensitive coating.

According to the invention there is provided a method of photographically exposing a substrate-mounted photosensitive layer to an original pattern to produce in a predetermined total exposure time a developable image of said pattern, wherein said original pattern comprises a plurality of like individual structures arranged in a regular array on a member or on each of a plurality of members, said method comprising photographically exposing said photosensitive layer successively at least three times, each successive exposure being to different individual structures of said regular-array pattern for a period of time less that said predetermined total exposure time and such that that exposure alone is insufficient to produce said developable image.

In a preferred embodiment of the invention, the total exposure time necessary for the transfer is divided into a plurality of successive component exposure phases, and, if the pattern present on the original is composed of a plurality of like individual structures arranged in a graticule distribution, the original is displaced by at least one graticule division in relation to the substrate before each component exposure phase, or the original is exchanged for a similar original before each component exposure phase.

Provision is preferably made for the original to be displaced by an integral multiple of the graticule division in relation to the substrate before each component exposure phase.

In the production of originals, for example of photo-masks, which are needed for the production of semiconductor devices or printed circuits, various statistical or systematic errors occur which prevent satisfactory transfer of the original structure to the substrate. Photomasks for semiconductor devices are generally produced by means of the known "step-and-repeat" method, wherein the starting point is an individual structure, and this structure is repeatedly reproduced on a film, and the individual structure or the film is displaced by tht prescribed graticule measurement of the whole mask, before each reproduction process. Already during the production of this mask, faults may be caused by particles of dust or holes in the photographic emulsion, and may lead to rejects, which increase the costs, during the production of the semiconductor devices. Further sources of error result from the wear of the working masks, their soiling in the course of numerous operational processes, or during the duplication of an original mask. Further rejects may occur during the transfer of the mask pattern to the semiconductor surface coated with photolacquer, as a result of faults in the optical system used for the reproduction or as a result of dust in the path of light.

The sources of error indicated can be eliminated completely by means of a preferred method according to the invention.

The method according to the invention is based on the principle of integrating the incident light. The exposure is only complete if the whole quantity of light is introduced in a single exposure step, or the x*th* part of the total amount of light necessary is introduced in x partial exposure phases. It must be borne in mind that the total exposure time depends on various factors. These include, for example, the nature of the photolacquer and its thickness. The light spectrum, and the size of the structures to be transferred. Thus, with a specific photolacquer for example, the total exposure time may vary by ± 1 minute, if a variation in the size of the transferred structures of $\pm 20\%$ is accepted.

Now if, in accordance with a preferred embodiment of the invention, the photo-lacquer is exposed with a fixed relative position of the

[*Price 25p*]

mask in relation to the substrate, for only a fraction of the total exposure duration, and then the mask is displaced in relation to the substrate by an integral multiple of the graticule divisions, then any fault which is present appears at a different place before the next partial exposure. If the total exposure duration is divided into x partial exposure phases, however, although the fault appears in x positions, it is only transferred thereby the x*th* part of the total amount of light and therefore does not become apparent. In this manner, the fault is completely eliminated.

It can be shown theoretically to be particularly advantageous for the total exposure time to be divided into more than two partial exposure phases; three to five partial exposure phases have proved economical in experiments and, in the majority of cases, sufficient to eliminate the faults. Considerably more partial exposure steps may, however, naturally be selected if the resulting additional expenditure is justified by the improved result.

By way of example, embodiments of the invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 shows one form of working mask having an error in the original pattern;

Figure 2 shows the same form of working mask having a different error in the original pattern, and

Figure 3 shows the result of full exposure of the working mask of Figure 2 by the method according to the invention.

The working mask 1 may be a negative mask, as illustrated in Figures 1 and 2, such as is needed for example for the production of a plurality of like diodes. The structures 2 appear transparent with a layer which is otherwise impermeable to light. In Figure 1, a structure is illustrated wherein structures are completely obliterated by faults present in the region 3. Another kind of fault is illustrated in Figure 2. Here an unwanted giant structure is reproduced through a faulty area 4 and with exposure with only a single exposure phase would lead to the production of a giant diode. Figure 3 indicates in broken lines that, on displacement of the mask, the fault always appears at a different place and so is only reproduced with the x*th* part of the amount of light in relation to one place. Figure 3 likewise shows the result of the exposure after the total exposure time has been divided into five partial exposure phases of equal length. Before each partial exposure step, the mask has been displaced relatively by an integral multiple of the graticule division. As Figure 3 shows, no faulty area is any longer distinguishable in the structure reproduced. All the diode structures are reproduced true to the original.

Experiments have also shown that even a three-part exposure time may be sufficient. If there are bright additional structures in the mask, one third of the exposure is effected through the faults and two thirds through two undamaged structures. It is true that the exposure may still be too great at the point at which the fault is present; but the fault is eliminated. With dark faults, that is to say with structures absent at certain places, the amount of light introduced in specific regions only amounts to two-thirds of the total amount of exposure. But since full development begins already with half the amount of light, the structures nevertheless appear in the developed photolacquer layer, even though somewhat too small in size.

In general it may be said that as the number of displacement and partial exposure steps increases, the probability of eliminating the faults and of adhering to the dimensions of the structures reproduced is increased.

With the division of the total exposure time into five partial exposure phases outlined in the example, the total exposure duration was between four and five minutes. A semiconductor wafer which is covered with a layer of oxide or nitride at the surface adapted for the transfer of the pattern, and which in turn is coated with a photolacquer layer, served as a substrate. The developed photolacquer layer may serve, for example, as an etching mask for the subjacent oxide or nitride which in turn may be used as a diffusion mask for example, after this etching process.

The above-described, exemplary method according to the invention has the advantage, apart from the advantages already outlined, that the blurred edges present with a single exposure step are eliminated. Graticule errors are likewise compensated by the method described. Fault-free mask copies and metal-glass masks can also be produced by means of a method according to the invention. For the metal-glass mask, a glass disc is used as a substrate and is covered with a metal layer at its surface. During the production of mask copies, the substrate consists of a suitable material, for example of film material.

In order to carry out the method described, devices are preferably used which comprise two cross-tables. The one cross-table serves, as usual, to centre mask and wafer, the relative displacement of the mask in relation to the wafer is then carried out by means of the other cross-table.

Instead of the relative displacement of the mask in relation to the semiconductor wafer as described, there is also the possibility of exchanging the mask for a similar mask in the same adjusted position as its predecessor, before each partial exposure step. In this case, for example, five similar masks would be produced for example, be accommodated in a magazine, and be arranged in succession, in an adjusted position in relation to the substrate, between the exposure phases. Mask errors can be eliminated in this manner because it can be assumed that faults would appear at different

points in five masks which were produced in independent processes. In addition, if the mask is changed before each partial exposure phase, masks can be used which only contain a specific pattern once. This applies, in particular, to printed circuits. On the other hand, faults in the image-forming lens cannot be avoided by exchanging the mask.

The method according to the invention is suitable for the production of semiconductor devices of all kinds, particularly diodes, transistors and integrated switching circuits which are produced by means of the planar technique. In addition, printed circuits can be produced by the method described if a metal coated board of insulating material is used as a substrate.

WHAT WE CLAIM IS:—

1. A method of photographically exposing a substrate-mounted photosensitive layer to an original pattern to produce in a predetermined total exposure time a developable image of said pattern, wherein said original pattern comprises a plurality of like individual structures arranged in a regular array on a member or on each of a plurality of members, said method comprising photographically exposing said photosensitive layer successively at least three times, each successive exposure being to different individual structures of said regular-array pattern for a period of time less than said predetermined total exposure time and such that that exposure alone is insufficient to produce said developable image.

2. A method as claimed in Claim 1, wherein the one member and the substrate are displaced relative to one another by an integral multiple of the array divisions between successive exposures.

3. A method as claimed in Claim 1, wherein each successive exposure is from a different member.

4. A method as claimed in any preceding claim comprising three to five successive exposures.

5. A method as claimed in any preceding claim, wherein said successive exposures are each of equal time.

6. A method as claimed in any one of Claims 1 to 5, wherein the or each member comprises a photomask and the substrate is a semiconductor body.

7. A method as claimed in Claim 6, wherein the semiconductor body is coated with an oxide or nitride layer at the surface on which the pattern is to be received and the layer is coated with a layer of photo-lacquer as said photosensitive layer.

8. A method as claimed in any one of Claims 1 to 5, wherein the or each member comprises a photomask and the substrate comprises a metal-coated board of insulating material suitable for the preparation of a printed circuit.

9. A method as claimed in any one of Claims 1 to 5, wherein the or each member comprises a photomask and the substrate is a material suitable for producing a copy of the photomask.

10. A method as claimed in any one Claims 1 to 5, wherein said substrate comprises a glass plate with a metal layer on the surface thereof.

11. A method substantially as described herein with reference to the accompanying drawings.

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1334377 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG.1

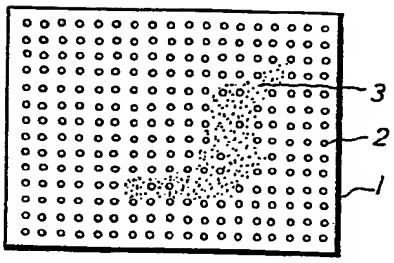

FIG.2

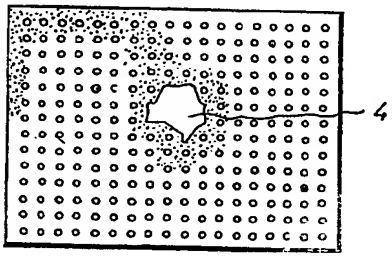

FIG.3